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of the country from the Pacific to the North Sea (Atlantic), the difference of level between the two seas, a section of the Republic from E. to W., showing the height of all the hills and all the cities, towns, and villages, and much other information hitherto unpublished.

I am, Sir, your very obedient servant,
A. VAN DE GEHUCHTE, *Engineer.*

XV.—*On the Fine Regions of the Trade Winds.* By THOMAS HOPKINS, M.B.M.S., Vice-President of the Manchester Literary and Philosophical Society.

Read, June 14, 1858.

IT has been abundantly shown that there are certain elevated lands which form areas of condensation of aqueous vapour, and consequent atmospheric vacua, towards which winds, known as trade winds and monsoons, blow over wide oceans. These winds, as they approach the places of condensation, loaded with the vapour they have taken up from the water over which they have passed, become stronger, and are frequently boisterous and rainy. It has also been proved that towards these same areas other, which may be called collateral winds, that are dry, blow from cool to warm latitudes, over lands, making such lands arid in their general character, and constituting them dry countries.* The trade winds and monsoons have also been traced backwards, over the oceans, from the areas of condensation to the parts where the winds appear to take their rise, and where fine weather is generally found.

But as these fine parts over the ocean bear a certain resemblance to the arid countries that have been pointed out, it may be worth while to advert to them again, in order more fully to understand their peculiar character, ascertain their geographical distribution, and the kind of circumstances that are associated with their movements, including the sources from which the air is supplied.

Condensation in Australasia gives birth to the trade winds of the southern tropical Pacific Ocean; and near the Australasian islands the winds are of considerable strength, and occasionally stormy. But as has been before stated, more to the E., excepting during the summer monsoons of this ocean, the same winds are milder and steady, until at last, nearer to the American continent, they breathe only as gentle zephyrs. Opposite to the Island of Juan Fernandes, in say 32° of latitude and 90° of west longitude, until the equator is approached, a steady and mild trade wind is generally felt; and from that longitude to the Marquesas Islands the increase in the strength of the wind is not great.

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* *See* vols. xxvi. and xxvii. of the Journal of the Royal Geographical Society.

In the Pacific Ocean of the northern hemisphere, within the tropics, the same kind of weather is found, extending westward from say the 120th degree of longitude over nearly the whole of the northern tropic, where the ocean is not studded with islands. This includes the large space between the group of the Sandwich Islands and the equator. These two fine regions of this great ocean no doubt obtained for it the epithet of "The Pacific," and those portions well deserve the name.

The winds, though mild in their character, and at first slow in their movements, occupy a large space on the surface of the globe, and the quantity of air which passes over that space must be great. This naturally suggests an inquiry as to the source whence the air is supplied. A large mass of it could not continue to flow on the surface over the ocean from the eastern to the western side unless the eastern side was supplied with an equal quantity from some other part. In a wind the motion of the air is produced directly by gravitation operating to restore a disturbed equilibrium, and therefore the force which is in action is really to be found in the superior weight of the air at the beginning of the wind, although the existence of a comparative vacuum at its termination enables that force to put the air in motion. We have, however, yet to learn from what quarter the aerial material really comes, and the form and manner in which atmospheric pressure moves the air in the way in which it is impelled on the eastern side of the Pacific. The general idea entertained on the subject appears to be that, owing to a difference of temperature in different parts, one mass of air presses against another, and that the heavier air, acting as a prime mover, forces the lighter forward; and this general idea seems to be associated with the commencement of the Pacific trade winds. But what proofs are there that air, either from the E. or from the S., in the lower regions of the atmosphere, primarily and by its superior weight pressed the whole mass across the southern tropical Pacific? The Cordilleras of the Andes form an impassable barrier to the flow of air on the eastern side of that ocean, and farther southward there is a general wind that blows across the whole of the ocean from New Zealand to Western Patagonia, in which latter country this wind terminates, producing there a large amount of rain. But before the place of commencement of the south-eastern tropical trade wind is reached off Juan Fernandes, there are no indications of the air being forced towards the W. by any kind of movement in the part where the trade wind is first found. On the contrary, the locality is calm, and certainly does not show by any motion the action of a prime moving force.

The same general features are presented to the view in the

Northern Pacific Ocean. As in the southern, a wind here blows across the ocean to the N. of 35° of latitude, from the W. to the E., which is from Asia to America; and then a N.W. wind blows off California towards the Isthmus of Panama. Yet near to this last named wind a calm space is found, and then a gentle N.E. trade wind begins within the northern tropic, in about the longitude of say 110° W., and it continues blowing over the northern tropic, increasing in strength as it proceeds across the whole breadth of the ocean. Now, whence comes the supply of air to feed this N.E. trade wind, and by what disturbance or force is it primarily moved? These are questions to which no satisfactory answer can be found in meteorological works which recognise the Hadleian theory of winds, and therefore that theory may for the present be discarded from our consideration.

We have seen that in large areas of condensation of vapour there are ascending atmospheric currents, produced by the condensation, which warms and expands the air in the part, and permits it to be forced up by that which is heavier. The lighter air, thus forced to ascend to a height where it is subjected to less incumbent pressure, must expand and cool in the higher regions; and the process of condensation being continued by this cooling, the ascension and expansion of the air must also continue, until the whole of the movements of the air resolve themselves into an expansion and overflow of light air in the higher regions, and a pressing and rushing in of heavier air in the lower where the trade wind is blowing. The extent of both the upper and the lower currents will depend on the amount of vapour condensed in the part, and the interference of other areas of condensation with them. In the lower regions of the Pacific the air presses at first gently from the E. towards the W., and in the higher regions, having been warmed by condensation of vapour, it must expand and may flow back from the W. to the E., possibly to that part where the trade wind begins. Admitting this, we must have in the southern tropical Pacific an ascending atmospheric current on the western side, and a descending current on the eastern side, the former concentrated and energetic in its action proportioned to the amount of vapour condensed within a limited space, and the latter diffused and mild, because its descent takes place gradually over a large area, but the latter current having a constant tendency to correct the disturbance made by the former, and to restore the natural equilibrium of atmospheric pressure. It is not, however, necessary to suppose that all the air which ascends at one end of a trade wind passes through the higher regions to the other end, where the lower wind is first felt near the surface, seeing that some parts of the upper current might successively descend and mix with the higher portions of the lower, the remaining part alone of the upper current reaching the extreme end of the line, or flat elongated circle of the two winds. The form of the movements would be determined by the unequal statical pressure of the different portions of the atmosphere, and the shape and elevation of the comparative vacua that are created by condensation; but an equilibrium would be soon established, and the air would remain at rest, if for a short time vacua ceased to be formed.

In like manner, within the northern tropic, condensation of vapour over the Philippine and other islands of the Great Archipelago must produce ascending aerial currents, which, flowing above, back towards the E., may descend to the lower regions on the eastern side of the Pacific to feed the never ceasing N. E. trade wind. It is evident that in this case, as in the other just named, the air of ascending streams cannot remain and accumulate in the elevated parts where the ascent takes place—it must flow away somewhere; and in the absence of special information respecting it, we are at liberty to presume that it may go to feed the lower current. There is no indication of an adequate supply of air coming from any part of the lower regions off California, nor from any part nearer the equator, as has been supposed in former papers, and it may consequently be presumed to come from the upper regions, near the beginning of the trade wind. In the present state of our knowledge of this subject conclusive evidence cannot be adduced. To navigators we are indebted for what we know of these parts, and their general accounts accord with what has been here advanced. In the calmer parts, near the commencement of the trade wind, the sky is represented as being very clear, and so it must be if the air descends there from the upper regions: and the sky remains unclouded over a very large geographical space, until the air has had time to take up fresh vapour by evaporation from the sea. This dry state of the atmosphere is in accordance with the supposition that the air has recently descended from an elevation where, from lowness of temperature, much vapour cannot exist, and is therefore in its favour. It is true the trade winds, when first observed, appear to move obliquely, inclining a little from colder to warmer latitudes, and approaching each other at their terminations; but their passage in the lower regions from still colder latitudes cannot be traced in this ocean, and therefore we are at liberty to presume that instead of coming from adjoining low parts, the air which feeds them may have descended from the upper regions.

The best evidence we have of the immediate source of the air in the trade winds of the Pacific is to be found in its degree of dryness. All accounts represent them as being at first, and to a considerable extent, accompanied by a clear sky; but I have met with no register of the humidity of the air. The researches that are now in progress, by Americans as well as English, to improve our knowledge of nautical geography, will probably give fresh information; but it is particularly desirable that there should be registrations of the wet and of the dry bulb thermometers in the parts treated of. If we were in possession of such registrations over a few lines of the Pacific from E. to W., a fair inference might no doubt be arrived at respecting the sources of the great masses of air which constitute the trade winds of this ocean.

The following are extracts giving an account of the state of the atmosphere in the eastern part of the Pacific, and will probably be thought sufficient for the present. The author of 'Two Years before the Mast' says, when off Juan Fernandes:—

> "At the close of the watch a few trade-wind clouds shut the island out from our view, and the next day (Nov. 27) we were out of sight of land. We caught the S.E. trades, and ran before them for nearly three weeks without so much as altering a sail."

Melville in his account of the Marquesas Islands in page 8 says:—

> "The light winds were sweeping up towards the islands: all that we had to do was to square the yards, and keep the vessel before the breeze. The sky presented a clear expanse of the most delicate blue; but the most impressive feature of the scene was the almost unbroken silence that reigned."

Darwin writes, p. 480:—

> "Oct. 20.—Sailed from the Galapagos, and in the course of a few days got out of the gloomy and clouded region which extends during the winter from the coast of South America. We then enjoyed bright and clear weather while running pleasantly along at the rate of 150 or 160 miles a day before a steady trade wind. The distance to Tahiti is 3200 miles."

Simpson, in his 'Journey round the World,' when in the Northern Pacific says:—

> "We soon lost sight of California, while a fine breeze from the N.W. carried us in three or four days into the region of the N.E. trades. On catching these in the latitude of 27° we were in about longitude 118°. As our port, Honolulu, was only 6° to the S. of us, and 40° of longitude from us, we steered W.S.W. under all our canvas on a voyage of fully 2300 miles. During the twelve days of our run, our breeze, though it ranged from N.E. to E.S.E., was yet uniformly fair, and so equable that we never took in either studding or sky sail during the whole of our course. Our rate of sailing varied from 6 to 11 knots an hour."—p. 413.

Over the Atlantic Ocean we find similar phenomena, in kind, if not in extent, to those in the Pacific, allowing for certain known differences in the localities. Navigators who pass the Cape of Good Hope by the usual route in the Southern Atlantic towards the equator, speak of the fine weather they uniformly have when they enter the S.E. trade wind. As in the Pacific the weather continues fine as the equator is approached, but being disturbed by the Island of St. Helena, and gradually losing its clear character near the Brazilian coast. Here also registrations of the dew-point and the temperature, or what would be better, of wet and dry thermometers, would enable the inquirer to infer what was taking place in the atmosphere where the wind arose. Ascended air with little vapour in it may possibly be supplied from the area of condensation in America, where this wind terminates; but a knowledge of the hygrometrical state of the air in the district around would enable persons to judge whether descent may or may not be safely inferred.

In passing from Madeira and the Canary Islands towards the Caribbean Sea, the same kind of clear skies is generally found near the commencement of the N.E. Atlantic trade-wind, where we fortunately have some accounts of the dryness of the air. General Sabine at one time found that while the temperature of the air was 66°, the dew-point was only 37·5. This dryness has been attributed to the neighbourhood of the great African desert, and the dust that has been long observed to fall on the decks of ships traversing the eastern part of this wind was formerly supposed to come from the desert. But recently samples of this dust have been subjected to careful examination by Ehrenberg, and by him it has been found to consist in a considerable degree of very thin and minute shells, which it is presumed may have been brought from South America, as in the soil of that country alone are some of these shells met with. It is, however, evident that the shells could not have been borne through the atmosphere from South America unless a current of air flowed in the higher regions across that part of the ocean. If therefore we are to credit the various accounts given of this shell-dust, we are constrained to admit that an upper current flows over the northern tropical Atlantic from America towards Africa, and of course in an opposite direction to the trade wind below: and as the dust falls the most freely in and near to the part where this trade wind begins to blow, we may admit that the upper wind descends there. This would account for the dryness of the air in this part without obliging us to suppose that it had come from the African desert, for which little countenance is given by known facts. It has been often observed that clouds in the higher regions passed over the Caribbean Sea in an opposite direction to the trade winds; but although those clouds travelled eastward towards Africa, the prevalence of the Hadleian theory caused them to be supposed to be passing to the N., whereas they may be presumed to have flowed in the same current that conveyed the dust.

Mr. C. Darwin, when at St. Jago, Cape de Verde Islands, at one time found the dew-point 29·6 below the temperature. But he also says that:

> " Generally the atmosphere is hazy, and this is caused by the falling of impalpably fine dust. The morning before we anchored at Porto Praya I collected a little packet of this brown-coloured fine dust. Mr. Lyell has also given four packets of dust which fell on a vessel a few hundred miles northward of these islands. Professor Ehrenberg finds that this dust consists in great part of infusoria with silicious shields, and of the silicious tissue of plants.

The infusoria, with the exception of two marine species, are all inhabitants of fresh water. From the direction of the wind, wherever it has fallen, and from its always having fallen during those months when the Harmatan is known to raise clouds of dust high into the atmosphere, we may feel assured that it all comes from Africa. It is, however, a very singular fact, that although Professor Ehrenberg knows many species of infusoria peculiar to Africa, he finds none of those in the dust which I sent him; on the other hand he finds in it two species which hitherto he knows as living only in South America. The dust falls in such quantities that vessels have run on shore owing to the obscurity of the atmosphere. It has often fallen on ships when several hundred and even more than 1000 miles from the coast of Africa, and at points 1600 miles distant in a N. and S. direction."—p. 193.

I have shown that there are no strong ascending currents to be traced over the great African desert. The Harmatan blows from it during our winter months when tornadoes take place over the equatorial Atlantic, and towards these tornadoes the Harmatan blows as a lower wind. But it is at the same season that the valley of the Orinoco is dry; and the strong winds that then sweep over that valley evidently go to the Southern Andes, at the time when much vapour is condensed there, and strong ascending currents are thereby created; in some of which, or in others in contact with them, the dust may be carried up, and afterwards borne across the Atlantic. In the higher regions this wind would blow from the W.; but if any of it should descend, and press into the trade wind below, in any part of its course, it would become a descending feeder to that trade wind, turning back and becoming a part of it: and near the beginning of the trade this descended current would in the lower regions seem to come from the African desert.

Lieutenant Maury appears to conclude, with confidence, that the Atlantic dust comes from South America, and he states facts which indicate that some of it, at times, proceeds over Africa as far as Germany, where it has been collected and examined. Visitors to the lofty Canary Islands have noticed that a wind above was often blowing in a contrary direction to the trade wind below. From the researches now making over the regions of the ocean we may hope to obtain more information on this subject, and it is evidently desirable that we should be informed whether the dust falls equally at all times of the year, or whether the great showers of it take place only when the valley of the Orinoco, where the shells are found, is dry and windy.

From the various phenomena that accompany the commencement of the four trade winds of the Pacific and Atlantic Oceans which we have been examining, and the circumstances that surround them, there are then reasons for inferring that atmospheric currents pass through the higher regions in a direction contrary to the trade winds below; and that some of the air in these upper currents, having had much of its vapour condensed where it ascended by the cold due to the elevation, at last comes down as a dry wind in those localities near the beginnings of the trade winds, which are so free from rain or clouds.

In the Indian Ocean near the equator constant trade winds, such as those of the Pacific and Atlantic, are not found, and accordingly there are no localities remarkable for having constant fine weather, such as that which has been just adverted to. But the monsoons of the Indian Ocean present similar features to the trade winds of the Pacific and Atlantic, though not alike in all respects. The south-west monsoon begins to blow over the ocean, and near to its commencement the locality is distinguished for having a season of fine weather. Incidental allusions to this fact may be met with in accounts of navigators who pass from India after having crossed the equator to go towards the Cape of Good Hope. But it is particularly asserted that in the northern part of the Mozambique Channel the season of the south-west monsoon is the fine season ; and from this part proceeding across the ocean to Hindustan, the sky becomes less clear as the aerial current approaches India, where it becomes the wet and stormy south-west monsoon.

But if the air found in the Mozambique Channel descends there from the upper regions, whence does it come ? Had it been carried up in ascending currents over the Malabar hills, or the more distant Himalaya mountains, and passed in upper regions across the Indian Ocean to the Mozambique Channel ? No known facts warrant this supposition. It is not, however, necessary that we should presume that the air which descends in a fine locality has come from the terminus of the same wind that it feeds. There are other areas of condensation in the neighbourhood, as at the Cape of Good Hope, over the large Islands of Madagascar and the Mauritius, from which dried air may possibly descend to feed the south-west monsoon. The proposition is, that air which has been dried by condensation of some of its vapour in high regions descends in some other parts to the lower regions as dry air, making the locality fine ; but it does not follow that it must descend to feed the same stream that had furnished it. Whether it does or does not, will depend on local position and statical pressure, the ascended air flowing in the upper regions perhaps towards the nearest wind to feed it, rather than towards that from which it had ascended. In the present state of our knowledge the immediate source of the air that constitutes the commencement of the south-west monsoon must be considered unknown, and we must rely on analogy alone in conjectures respecting it.

The *north-west* monsoon, in the earlier part of its course, is found over land, as over Persia, the desert of Bokhara and Central Asia, all of which countries are dry. If it consists of recently descended air, it would seem to have come from many small areas of condensation distributed over the mountains of Asia and Europe : the passage of the air from colder to warmer latitudes would, however, tend to make it dry. Arabia and much of the eastern coast of Africa, and the seas adjoining, have nearly cloudless skies, but beyond this fact we know little of the atmosphere in this part of the world. The Himálaya mountains and the East Indian Archipelago are the two great areas of condensation of vapour in the neighbourhood of the Indian Ocean, and reasoning from the general principles here recognised, we must infer that large quantities of air, within these areas, are borne to high regions, and in some parts come down to low ones, but as to where they descend we have no clear indications.

Of the higher regions of the aerial ocean we have indeed little knowledge, excepting among mountains, where the air is often disturbed by local causes; but that which is borne aloft does not produce dense clouds after it has been deprived of its vapour, and the heat which is liberated when rain is produced is left to expand the upper air, having little vapour, and this expanded air with its small portion of vapour is soon diffused in the higher regions where dense clouds do not originate. Those light ones that are seen at great elevations over large plains or extensive oceans, being at a great distance, appear to move slowly, and the movements have been but little noticed. The higher regions have received little attention from meteorologists; we are therefore left to infer as well as we can, from a few facts, what is generally taking place in those regions. The striking circumstance, that very large masses of air flow unceasingly near the surface of the globe, over wide extents of land and sea to certain parts where they evidently ascend to the higher regions, compels us to infer that these masses must in other parts descend to the lower, and we are obliged to take such indications of the places of their descent as can be discovered. But wherever they come down, whether in a neighbouring part or at a great distance, they must be dry, having been deprived of much of their vapour by cold.

In the rainy sea of the Atlantic, as well as in other localities of tornadoes and typhoons, when storms occur, large quantities of air must be borne to the higher regions to descend in other parts according to the laws of statical pressure; and a summer thunderstorm in colder latitudes, such as the British islands, will produce similar results; but there seems reason to presume that in many of such cases the air which ascends soon comes down again, as in a few hours fine weather often follows the storm,—it being commonly said that the storm clears the air, and a hygrometer shows that it has become drier.

It has been shown that there is no direct evidence that air, warmed in a belt near the equator, ascended there and overflowed towards the poles; but when it ascends continuously in one part of the tropics it must descend in some other part, and it is reasonable to presume that directly or indirectly it comes down as a feeder to winds that blow with equal constancy.

There certainly are winds that blow overland from polar towards tropical regions, but the tropical air that feeds the principal of these winds, flows, not in the higher regions, but on the surface of the ocean, passing from the tropics over the low level of the sea. In the Northern Atlantic southern winds blow between Ireland and Norway on the E., and Labrador and Greenland on the W., far into the Arctic Ocean, in their course parting with much vapour; and in the Northern Pacific western winds go far N. on the American coast, furnishing rain and snow. But these masses of air appear to return over continental lands, in both the old and new worlds, to regions of condensation in warm and moist parts. In the southern hemisphere winds blow eastward over the sea from the cold regions of Victoria Land to the rainy district about Cape Horn; but to the W. of Victoria Land, extending beyond the meridian of the Cape of Good Hope, the flow of air in the lower regions is represented by navigators as being towards the South Pole.

Condensation of vapour, by irregularly disturbing the atmosphere at various heights, puts the air in motion at those heights, making it ascend in one part, and it must come down in another. Some of the areas of ascension have been described, and a few of descent, but there are innumerable others spread over the surface of the globe, every hill or place where heavy rain falls being to some extent an area of ascent, with the wind that blows towards it coming directly or indirectly from a region of descent. The whole aerial ocean, to a considerable height, is thus kept in a state of motion and change; and the invisible elastic vapour which is sent into the atmosphere by evaporation in one part, comes down as rain in another. The different quantities of vapour condensed in equal times in different localities, and the elevations at which the condensation takes place, modify the movements of the air in various degrees, and in all conceivable ways, but the nature of the processes is always the same.

XVI.—*Remarks upon the Amount of Light experienced in high Northern Latitudes during the absence of the Sun.* By Captain SHERARD OSBORN, R.N., C.B., F.R.G.S., Officier Légion d'Honneur, etc.

Read, June 14, 1858.

AFTER passing the winter of 1850-51 in H.M.S. *Pioneer* under the lee of Suffolk Island, in latitude 74½° N., I observed that discussions often arose as to the amount of light we Arctic navigators had really enjoyed during the past season of darkness, and that in